

MULTISPECTRAL SCANNING SYSTEM IN AN AIRCRAFT EXPERIMENT TO
RESEARCH EARTH RESOURCES

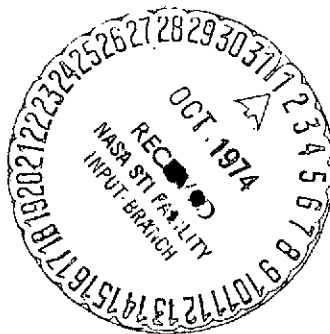
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MULTISPECTRAL SCANNING SYSTEM IN AN AIRCRAFT EXPERIMENT TO RESEARCH EARTH RESOURCES

G. A. Avanesov, I. V. Barinov, and V. D. Glazkov¹

A description of the systems comprising a preliminary model of the experimental complex for acquisition and processing of video information is presented. Preliminary results of the experiment are given. /30*

The complex aircraft experiment for researching earth resources conducted by the Institute for Space Research of the USSR Academy of Sciences in 1973 included the study of employing multispectral scanning systems to obtain imagery of the earth's surface in various spectral ranges, as well as objective information concerning reflective properties of ground objects. For the experiment, the Institute for Space Research developed a number of the following systems for the acquisition and processing of video information:

1. Multispectral scanning system (MSS) designed for acquisition of surface images simultaneously in 8 spectral segments in the long wave range 0.35-1.1 μ .
2. Digital video recording system (DVRS) for recording video information on magnetic tape onboard the flying laboratory in four selected spectral zones simultaneously.
3. Data preparation system (DPS) designed for the conversion of video information into a format suitable for processing in computers of the "unified" system. /31
4. Digital video recording interpretation system (DVVIS) designed to synthesize color and black and white images.

In addition to the systems cited, mathematical provision elements were developed to provide for the processing of video information on computers of the unified system. Airborne and ground systems, including the computer, comprised

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the preliminary model of the experimental equipment for collection and processing video information and designed for the following:

1. Investigation of the principles of constructing multispectral scanning systems and methodology for conducting experiments in the collection of video information with allowance for the characteristics of subsequent automated processing.
2. Acquisition of experimental material on the most representative regions of the USSR studied in the form of photo-television pictures and corresponding digital video recordings.
3. Development of independent methods for the automated processing of information based on actual material, converted to proper format for introduction into the computer.
4. Investigation of the presentation form of initial and processed video information for potential customers.

In addition to the directions cited in utilizing the experimental equipment model in resolving basic questions of problems in researching earth resources by long range sounding methods, several independent experiments in the interest of national economic departments could be conducted based on the experimental model. The bases for conducting similar experiments lie in the capability to transmit to branch organizations video information acquired during flight in the form of photographs and digital video recordings in modern computer equipment structure.

The diagram of the airborne segment of the experimental equipment, consisting of the two systems, MSS and DVRS, is shown in Figure 1.

The radiation flow, reflected by the earth's surface, strikes the oscillating mirror, which provides for the scanning of images at right angles to the aircraft's flight path. Oscillation of the mirror is achieved by a cam gear rotating through a reducer by a hysteretically synchronized electric motor. The primary scanning speed is 4 lines per second. The field of vision angle of the scanning device is 51° .

Via a passive mirror installed for design purposes, the radiation flow strikes the input objective lens which has in its focal plane a field diaphragm

that determines angle of resolution. The parallel flow of radiation formed by the collimator strikes the diffractive grating, differentiating it into spectral components. The differentiated flow strikes the radiation detectors via the collecting optics system. Amplification of the video signals from the radiation detectors is accomplished by a direct current amplifier.

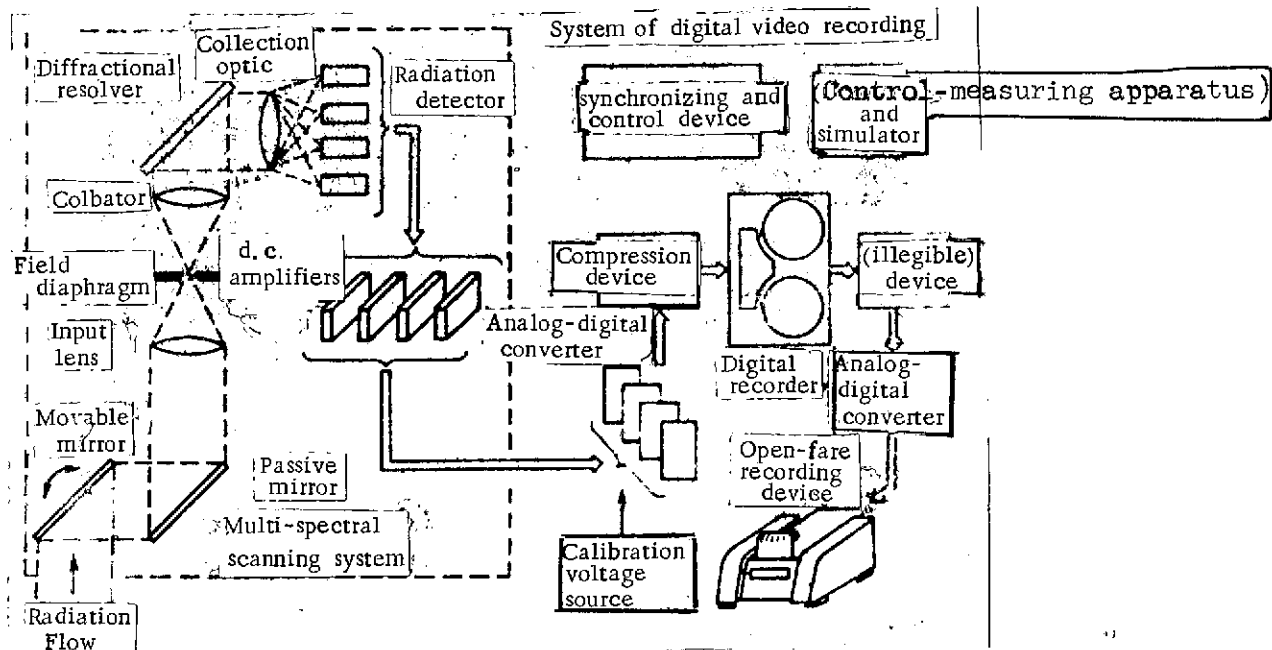


Figure 1. Diagram of the Airborne Segment of the Experimental Equipment.

The MSS system is installed onboard the aircraft on a gyro-stabilized platform, thereby reducing the effect of rolling and pitching on the geometric indices of the acquired images.

The dimensions of the MSS field diaphragm provide for the acquisition of 512 elements in each scanning line, 32 of which constitute the return flow. The relatively low resolution capability of the MSS was established as a result of the following considerations:

- to achieve a signal/noise ratio in each channel on the order of 200,
- to achieve resolution of terrain approaching that expected of satellite experiments,
- to limit the volume of information to that considered suitable for processing on a universal computer.

Further reduction in resolution capability of the MSS leads to a significant deterioration of the visual quality of the television pictures.

The diffractive grating was selected as a flow disintegrator for conducting experiments with various types of radiation detectors, as well as to provide the capability of varying spectral ranges. The diffractive grating and collecting optics enable 8 radiation detectors to be installed in the MSS by using the FEU-68* selected for its spectral sensitivity and silicon photodiodes.

After conducting a series of experiments with the onboard system, at the outset of the operation with the aircraft/laboratory, four spectral ranges were selected: 0.4--0.45, 0.5--0.55, 0.6--0.7, and 0.72--0.82 μ ; these ranges did not change throughout all the subsequent flights.

Electrical signals from the direct current amplifier output run to the inputs of the 4 channel digital video recorder system. Each channel of the DVRS utilizes identical octal discharge analog-digital converters having common source calibrated voltage. From the converter output, the octal discharge parallel codes pass through a compression device to the input (recording) of the 20 track digital magnetic recorder. For continuous monitoring of recording and image quality, information is simultaneously read with recording by reading heads (reproducing heads) and passes through a channel search device to the digital-analog converter. A like signal is reproduced on electrochemical paper by an open recorder apparatus as an image of the surface photographed.

Control and synchronization equipment provides synchronized signals to the MSS, and also the DVRS part of which are recorded on auxiliary tracks of the digital magnetic recorder:

- timing impulses, following with coded samples with a frequency of 8192 Hz
- channel markers, corresponding to the first recording channel, following with a frequency of 2048 Hz
- line beginning markers, corresponding to the formation time of the first element signal of each line of the first channel, following with a frequency of 4 Hz
- control discharge.

*Translator's Note: FEU = photoelectric amplifier.

The timing impulses and channel markers are designed to reproduce recordings from coded tracks of the magnetic tape and the distribution of coded samples by channel. The line beginning markers facilitate the search for information within each line during machine processing and reduces the probability of fragmentation in synchronization that might occur when coded samples drop out due to magnetic tape defects. The control discharge permits error control in coding that might occur in the digital video recording system.

Recording of video information on the digital magnetic recorder is at a tape speed of 0.25 mps, which corresponds to a recording density of 32.8 impulses/mm.

It is possible to record information from other instruments on free tracks, ^{/33} further allowing complex information coincident in space and time to be collected onboard the aircraft.

In addition to the primary systems comprising the aircraft set, the control-measuring apparatus is included; it is composed of a set of measuring instruments and simulators that permits the apparatus to be tuned during flight.

In this manner, as a result of the MSS operation onboard the aircraft/laboratory, digital magnetic recordings of the images are acquired in 4 spectral ranges, the elements of which are strictly coincident.

The digital recordings obtained from onboard the aircraft are transmitted to the ground-based systems, the schematics of which are presented in Figure 2.

Reproduction of the digital recordings in the form of photographic images allows video information to be presented in the normal format for decoding, thus making possible an objective evaluation of the advantages and shortcomings of this scanning method as compared with the photographic method. In conducting such evaluations, it must be considered that this method of scanning permits acquisition of surface images from not only the visible area of the spectrum, but also from the infrared, as well as in perspective and the ultra high frequency ranges. In addition, with the scanning devices, a somewhat more exact calibration of video-signals is possible, which, under maintenance conditions for video information metric properties in data transmission systems or in interim storage

systems, permits shifting to the objective method of processing by employing computer equipment. Therefore, despite the fact that acquisition of imagery by employing a multispectral scanning system with a large number of spectral channels cannot be considered an end in itself, a great deal of attention must be devoted in the ground-based systems of the experimental set to high-quality reproduction of digital video recordings in the form of photographs.

In the DVRIS system, a 20 track digital magnetic recorder is used, similar to that installed onboard the aircraft. The video-information is reproduced from the magnetic recorder via an intermediate recording device and a set of functional digital-analog converters, thence to a synthesis device for black/white images and an image synthesis device for conventional colors.

The synthesis device for black/white images is a photoregister with an electromechanical image developer. The video signal from the functional digital-analog converter output passes to a modulating light source. The color flow, modulated by the video signal, converges in the field diaphragm plane, determining the element dimension of the synthesized image. The field diaphragm aperture is designed for photomaterial fixed to a drum. Development of the image is accomplished by rotating the drum and by relocating the projection optics elements along its generatrix. The photoregister permits the acquisition of images having maximum dimensions 220X300 mm, with a resolution to 10 lin/mm. To ensure agreement of video-information acquisition track amplitude characteristics with the modulating light source parameters and the characteristics of the curved photomaterial, a functional digital/analog converter is used, which enables the reconstruction of practically any transmission function by using the method of linearly-broken approximation.

The image synthesis device for converting colors utilizes the same method for creating the scribing light beam and development. The video signals picked up from three channels of the digital video-recording modulate three modulating light sources. The modulated light flows are combined by a system of dichroic mirrors and fed into an optical system similar to that employed in the black/white photo-register. Functional digital/analog converters are used here as color correctors.

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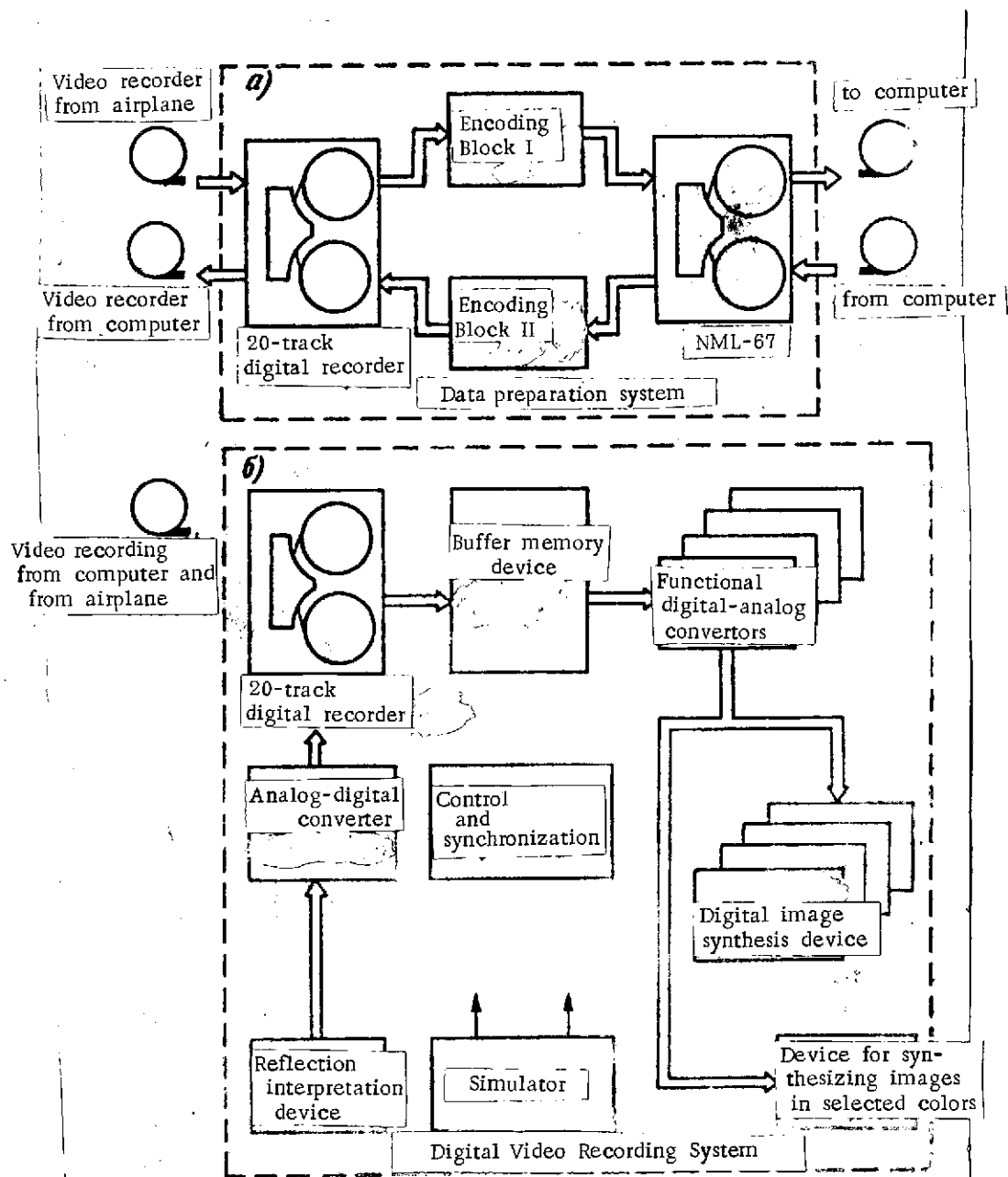


Figure 2. Schematic for Ground Systems:
a) Data Preparation, b) Interpretation of
Digital Video-Recordings.

An intermediate recording device is used to interpret the video-recording from the digital magnetic recorder which provides an asynchronous mode for reproduction of the video information. This mode is used for two reasons: mag-

netic tape speed stability is insufficient for high-quality reproduction of imagery and imagery acquired at constant scanning speed and variable flight speed requires scaling. Allocation of interpretation processes for information from the magnetic tapes and conversion of calculations into image elements by buffer memory on two lines permits transition to operations with independent index frequencies on buffer input and output.

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Scaling of the images is achieved by changing line length and values of inter-line intervals, which requires a flexible interpretation rate relative to the recording mode established onboard the aircraft. Change of video recording interpretation rate from the buffer memory device is accomplished by changing the timing pulse repetition frequency of the timing impulses created by the master input generating control and synchronization device.

Two basic modes are used to register the images: the modes differ in the plane of the photo-recordings: 5 and 10 lin/mm. In addition, the dimensions of a typical blank 108X300 and 54X300mm are varied accordingly.

In the black/white photo logging mode, with photo-recording field equal to 10 lin/mm, an open version of the apparatus is provided which will enable images to be acquired in 4 spectral zones on one blank, 220X300mm in size.

Photographic logging of images in conventional colors can be achieved only with a recording field of 5 lin/mm.

A simulator generating a series of both simple and complex signals of the type used for recording of video-information on board the aircraft is used to calibrate and tune the photo logging apparatus:

- constant digital combinations designed for initial setting of recording voltage and stripping of through "digit-colors" characteristics

- digital signals necessary for the acquisition of 7 colored strips on the photo-material, which permit correctness of tuning in the conventional color device (synthesis) to be judged

- digital graduated wedges, which provide operational control over the through characteristic of the recording track.

The capability for interpreting single photographic images is provided for in the DVRIS system. The device utilized for this purpose in this system is

constructed on the basis of the photo-telegraph device, the "Neva". The video signal acquired by using this device is coded into a format of the type used by the DVRS system, which enables single aerial photos to be processed by the same equipment.

The DPS system used to feed video information into the computer consists of two digital recorders and two re-recording assemblies for information. The magnetic recorder upon which the digital video-recordings are made is analogous to that installed aboard the aircraft. A second magnetic recorder, type NML-67, is included in the computer of the "unified" system. The digital video recordings received from the aircraft are re-recorded in machine format in the form of indeterminate length segments. A special program has been developed to interpret these recordings in the computer, utilizing disc storage.

In those instances where the results of machine processing may be presented in the form of numbers, tables, or graphs, external devices are utilized for transformation which are part of the computer system. Quite frequently, however, the results of machine processing must be presented in transformational form. Generally, such a necessity arises during computer solving problems of improving formation and decoding properties, during the synthesis of combined images based on multi-spectral video information, etc. To obtain images by means of machine processing, a corresponding digital video-recording is synthesized on magnetic tape, converted in a second channel of the DPS in a format suitable for use in the DVRS system. /36

Utilization of the combined DPS and DVRS systems permits, under predetermined conditions, the operation with video information in zonal format which is more widely distributed in modern computer equipment.

The aircraft experiment conducted in 1973 on researching Earth resources provided valuable experience in the utilization of multi-spectral scanning systems and automated processing equipment and abundant material for studying the more representative regions of the USSR.

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